Canadian Patent Office

587,174
Issued Nov. 17, 1959

Patent No. 587,174

Heat Transfer Method and Apparatus

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Application March 23, 1956, Serial No. 704,069
In the United States March 25, 1955
3 Claims

This invention relates to heat transfer equipment and has particular although not limited reference to heat exchange devices in which a congealable liquid and a coolant are circulated in heat transfer relation to one another to cool the liquid or to warm the coolant or both.

An object of the invention is to achieve the desired heat transfer results without excessive congealing of the congealable liquid.

Another object of the invention is to obviate misoperation of the heat exchange device resulting from local overcooling of the congealable liquid.

A further object of the invention is to present a generally new method of and apparatus for the prevention of congealing and the obtaining of maximum heat transfer efficiency, in the cooling of a congealable fluid.

Still another object of the invention is to introduce a principle of variable film coefficient in heat transfer between fluids in a heat exchange core.

According to its illustrative embodiment, the invention has particular reference to the lubricant circulating and fuel supply systems of aircraft and other vehicles which operate at times under atmospheric conditions of very low temperature, as on the order of 65°F below zero. At extremely low temperatures of this value the fuel is in a condition conducive to icing at the carburetor or fuel injectors. It is desirable, therefore, to warm the fuel to a more moderate temperature, and it has been proposed to do this by interposing in the fuel supply line a heat exchanger comprising essentially a core of thin wall tubes with the fuel flowing through the tubes and circulating engine oil flowing over and around the tubes. The engine oil is, of course, heated in the operation of the engine and in flowing through the described core rejects heat to the fuel. The temperature differential between the heated engine oil and low temperature fuel is so large that there is a tendency for the flowing oil to thicken and congeal about the tubes of the heat exchange core with the result that the rate of heat transfer drops off materially and the device becomes inadequate properly to warm the fuel.

The congealing tendency can be compensated for by constructing the core of the heat exchange device of such diameter and of such length that the amount of heat transferred is sufficient for the purpose even though part of the oil is congealed. A large core, as necessitated by this recourse, is undesirable for a number of reasons but most importantly because it is costly in terms of space and weight, both of which are critical criteria in the design of aircraft parts and accesories.

The instant invention has in view the provision of a heat exchange core conventional in its mode of heat transfer operation but introducing a generally new concept in the operation of such devices wherein different parts of the core accomplish in rejection of heat from one fluid to another according to different heat transfer coefficients. Still further, the invention has in view the making use of a further new concept in heat exchange devices wherein the individual tubes of the core are constructed to produce jet flow-turbulizing characteristics in the fluid flowing through the tube, materially increasing the ability of the tube to transfer heat. According to the illustrative embodiment of the invention the core tubes are constructed in part with such means for producing the jet flow-turbulizing characteristics of a fuel flowing therethough and are in other parts constructed without such means. Thus, and further in accordance with the illustrative embodiment of the invention, the inlet ends of the tubes are of a conventional cylindrical configuration whereas the outlet ends of the tubes are constructed for increase heat transfer capabilities as above described. It is proposed, and the parts are so constructed and arranged, that during its initial passage through the core, the low temperature fuel receives some heat from the oil but not a rate sufficient to cause congealing in the oil. Continued flow of the fuel then is in a stage of high velocity, turbulent, high heat transfer efficiency in which the fuel takes on added heat from the oil at a rate designed to produce the desired fuel temperature condition. In this stage of the operation, however, the differential between the engine oil temperature and the fuel temperature is not so great as excessively to lower the temperature of the oil.

According to the inventive concept, therefore, heat exchange apparatus is provided making use of high efficiency heat transfer concepts and so make possible a heat exchanger of acceptably small size and low weight and yet to avoid the problem of congealing which would normally be expected to result from use of a heat exchanger so characterized. Also, it will be understood that the invention has broadly in view the establishing and defining of a variable film coefficient of heat transfer and that this may be achieved by specifically different means and for specifically different purposes.

Referring to the drawings,

Figure 1 is a view in longitudinal section of a heat exchanger constructed in accordance with the illustrative embodiment of the invention;

Figure 2 is a view in longitudinal section of a heat exchange tube comprised in the device of Figure 1;

Figure 3 is a diagram showing the wall temperature of a conventional heat exchanger with constant film coefficient for fluids which do not congeal at operating temperatures; and

Figure 4 is a view similar to Figure 3, showing the wall temperature of a heat exchanger in accordance with the present invention, using a heated fluid congealable at operating temperatures.

As shown in Figure 1 a heat exchange device in accordance with the illustrative embodiment of the invention comprises a cylindrical open ended shell 10 in one end of which is installed a closure cap 11. In the other end of the shell 10 is a fitting 12 having a central opening 13 adapted to receive one end of a pipe (not shown) leading from the source of fuel supply. Interposed between the ends of the shell 10 and longitudinally spaced from one another are tube sheets or header plates 14 and 15 having openings therein to receive respective ends of open ended thin wall heat exchange tubes 16. The plate 14 together with closure cap 11 defines a chamber 17

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at one end of the shell 10. The plate 15 together with fitting 12 defines a chamber 18 at the other end of the shell. Fuel from the fuel source is admitted to chamber 13 by way of opening 13, and it will be understood that the fuel is supplied under a suitable pressure. From chamber 18, the fuel flows by way of tubes 16 to the oppositely disposed chamber 17 from which it leaves the shell 10 by way of a radial opening 19 therein. From the opening 19, in a manner which it is unnecessary here to consider the fuel continues its path to the engine.

Another radial opening 21 in the shell 10 provides for inflow of engine oil to the shell 10. Within the shell, the oil flows over and around the assembled core of heat exchange tubes 16 toward an outlet opening 22 over which may be superimposed a fitting 23. Baffles 24 and 25 may, as indicated, be installed in the shell to compel the oil to follow a circuitous path through the core, which path is in the main in cross flow relationship to the tubes 16 and in generally counterflow relation to the movement of the fuel. It will be understood that the several parts of the heat exchange device described are interconnected in a secure, leak proof manner, as by brazing. Further, the device will ordinarily include valve means regulating and controlling the flow of engine oil or fuel, or both, in order that the temperature of the fuel may be held at or about a selected predetermined value.

Considering the construction of the tubes 16 in greater detail, and referring to Figure 2, approximately one-half the length of each of the tubes 16 is continuously cylindrical in its configuration. The balance of the length of the tube is interrupted by longitudinally spaced apart annular beads 26. The described beads are short in length compared to the tube distance between adjacent beads, and constitute longitudinally spaced apart flow restrictors which tend intermittently to speed up the velocity of the fuel as it passes through the tubes. Further, the normal tube diameter beyond each restriction becomes in effect an expansion chamber in which the fuel flow becomes random and tubulent and may even reverse itself before being forced through the next succeeding restriction to repeat the turbulizing action in the next following expansion chamber. Along the beaded parts of the tubes 16, therefore, the flowing fuel is given added velocity plus turbulence for an increased rate of heat exchange between the oil and the fuel. A turbulence in the engine oil, produced by the external configuration of the tubes of the beaded portions thereof is thought further to add to the heat exchange efficiency. In the assembly of the core structure, the tubes 16 are placed with the smooth cylindrical ends thereof at the inlet end of the core, or that end facing inlet chamber 18. As a result, the relatively cold fuel enters the heat exchange core in an area in which the rate of heat transfer between the fuel and oil is comparatively low. In this first heat exchange stage, therefore, the fuel is warmed but not at a rate calculated to produce congealing of the oil around the tubes. As flow of the fuel continues, however, it encounters the beaded portions of the tubes and the rate of heat transfer rises rapidly, with the fuel reaching its selected temperature value as it is discharged into the chamber 17. Here again, however, the preliminary warming of the fuel provided in the initial stage of operation is sufficient to prevent a large loss of heat from the oil of the kind required for congealing of the oil.

Further in accordance with the illustrative embodiment of the invention the core structure is one of high density with the tube diameters reduced in size as compared to practices of the prior art. A greater surface area thus is achieved, helpful to a more rapid rate of heat transfer than has been known heretofore.

It may thus be seen that in the design of certain heat exchanger equipment it may occur that cold side fluid enters the heat exchanger at a temperature lower than the congealing temperature of the hot side fluid. In this type of device, it is desirable, and in fact necessary, for proper operation, to prevent congealing of the hot fluid as much as possible to maintain maximum heat exchanger efficiency. In accordance with the instant invention, it has been demonstrated and is herewith submitted that a variable film coefficient of heat transfer on the cold side may advantageously be used for the prevention of congealing and for obtaining maximum heat transfer efficiency, with all of the advantages of lightness in weight and smallness of size which the latter imports.

According to the illustrative embodiment of the invention, only two types of heat transfer surface on the cold side are here considered, these being the beaded tube and the plain tube. The reciprocal of the film coefficient is proportional to the temperature drop through the laminar layer of fluid adjacent to the tube wall. In the diagrams of Figure 3 and 4 hereof curves have been plotted in a representative manner, indicating respectively the temperature of the hot fluid, the wall temperature of the tube, and the temperature of the cold fluid. In Figure 3 the representation is that of a conventional heat exchanger with constant film coefficient for fluids which do not congeal at operating temperatures, this diagram being included in the drawings for purposes of comparison with Figure 4. There is in the illustration of Figure 3 no critical wall temperature to be concerned with, and the character and kind of heat exchange surface used may be selected solely with regard to the obtaining of maximum heat transfer efficiency. In the case of Figure 4, however, it is necessary to keep the temperature of the tube wall above the temperature at which congealing is promoted. The line "a" in Figure 4 defines a temperature value representing the minimum allowable wall temperature, below which congealing of the hot fluid results. From the hot end of the heat exchanger (point 1 of Figure 4) to about the mid part thereof (point 2 in Figure 4) the beaded tube is used. From point 2 to the cold end of the heat exchanger (point 3 in Figure 4) a plain tube is used to keep the tube wall up to temperature "a". A beaded tube used the full length of the heat exchanger, it will be apparent, would result in dropping the tube wall temperature below the allowable minimum and consequently in congealing on the hot side of the tube wall. It would be possible to maintain the tube wall at temperature "a" throughout the heat exchanger if a constantly varying film coefficient were used. Congealing can be prevented, however, and most of the potential efficiency can be realized by changing the cold side coefficient a limited number of times, in the manner here disclosed.

Thus, the line marked "Tube Wall Temp." could be made substantially straight and substantially to overlie the line "a" by a more strict application of the instant inventive principles. A variable film coefficient might, for example, be obtained by progressively decreasing the spacing of the tube beads from the cold-to the hot end of the heat exchanger. Also, the tube-bead spacing might be held constant while the depth of grooving of successive beads or sucessive groups of beads is varied. Combinations of the above effects also are possible.

The invention has been disclosed in its application to problems arising in the cooling of a congealable liquid. It is, of course, adapted to the solution of other problems wherein an exchange of heat according to a variable film coefficient may be desirable. In one

type of air to liquid heat exchanger, for example, it is desired to lower the temperature of a heated air by passing it through tubes like the tubes 16 hereof while water or another coolant is in contact with the external walls of the tubes. A tube beaded to a maximum depth over its full length would deliver a maximum rate of heat transfer, but at a cost in pressure drop usually greater than can be afforded. Hence a progressively changing film coefficient, as from a maximum at the hot end of the core to a minimum at the cold end may advantageously be used in an installation such as this one.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of obtaining maximum heat transfer efficiency without congealing in the bringing into heat exchange relation of a hot fluid which is congealable and a cold fluid which is initially at a temperature lower than the congealing temperature of the hot fluid, including the steps of providing dual heat transfer surfaces having respectively different heat transfer film coefficients, arranging said surfaces in series relation, and putting the fluids substantially in counterflow over said surfaces, the hot fluid first encountering the surface of higher film coefficient and flowing to the surface of lower film coefficient, and the cold fluid first encountering the surface of lower film coefficient and flowing to the surface of higher film coefficient.

2. A method of obtaining maximum heat transfer efficiency without congealing in the bringing into heat exchange relation of a hot fluid which is congealable and a cold fluid which may be at a temperature lower than the congealing temperature of the hot fluid, including the steps of providing a heat transfer surface constructed for a variable film coefficient of heat transfer, and arranging such surface in relation to the direction of flow of the cold fluid so that the surface encountered by the cold fluid is of a progressively greater heat transfer coefficient.

3. A method of obtaining maximum heat transfer efficiency without congealing in the bringing into heat exchange relation of a hot fluid which is congealable and a cold fluid which is initially at a temperature lower than the congealing temperature of the hot fluid, including the steps of providing dual heat transfer surfaces having respectively different heat transfer film coefficients, and putting the fluids over said surfaces in heat transfer relation, the cold fluid first encountering the surface of lower film coefficient and flowing to the surface of higher film coefficient, and the hot fluid progressing from one surface to the other while moving in generally cross flow relationship to the flow of the cold fluid.

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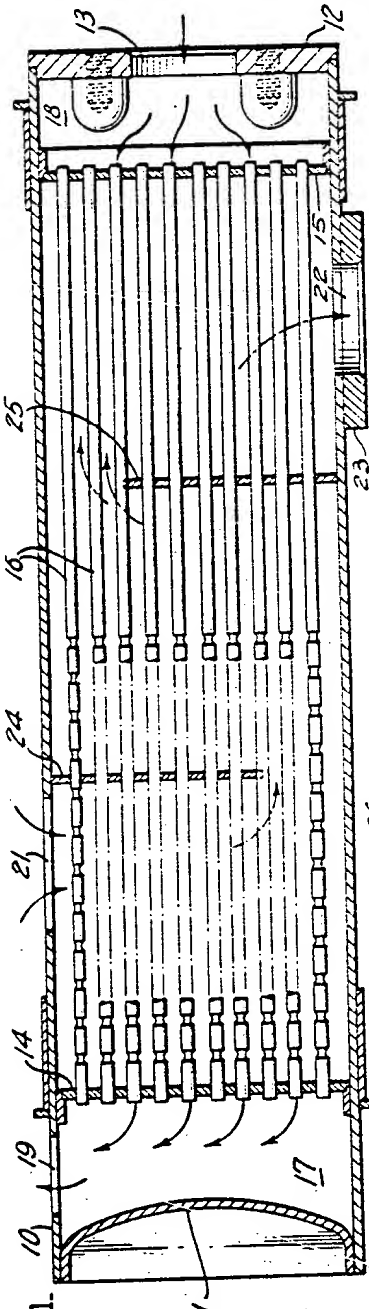

Fig.1.

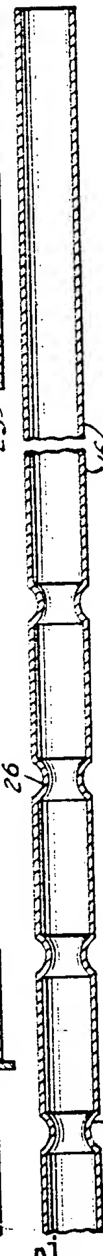

Fig.2.

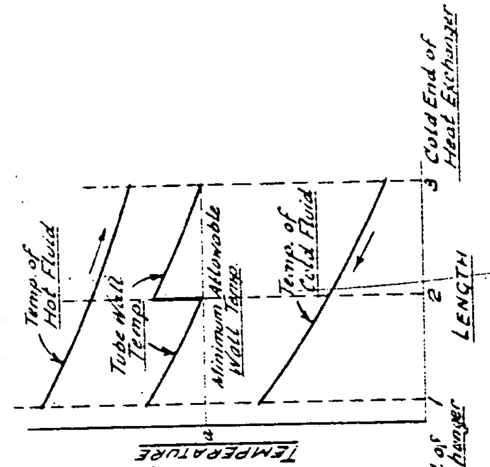

Fig.4.

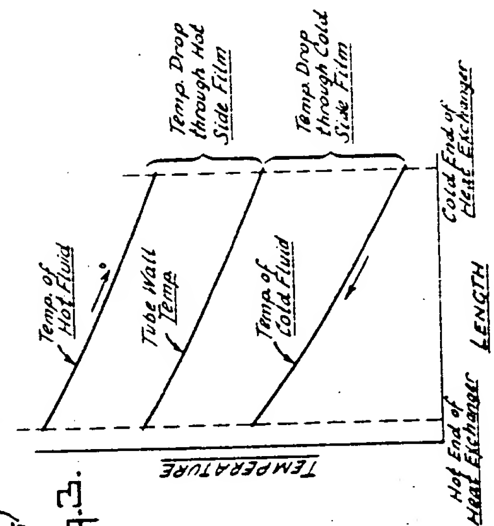

Fig.3.

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